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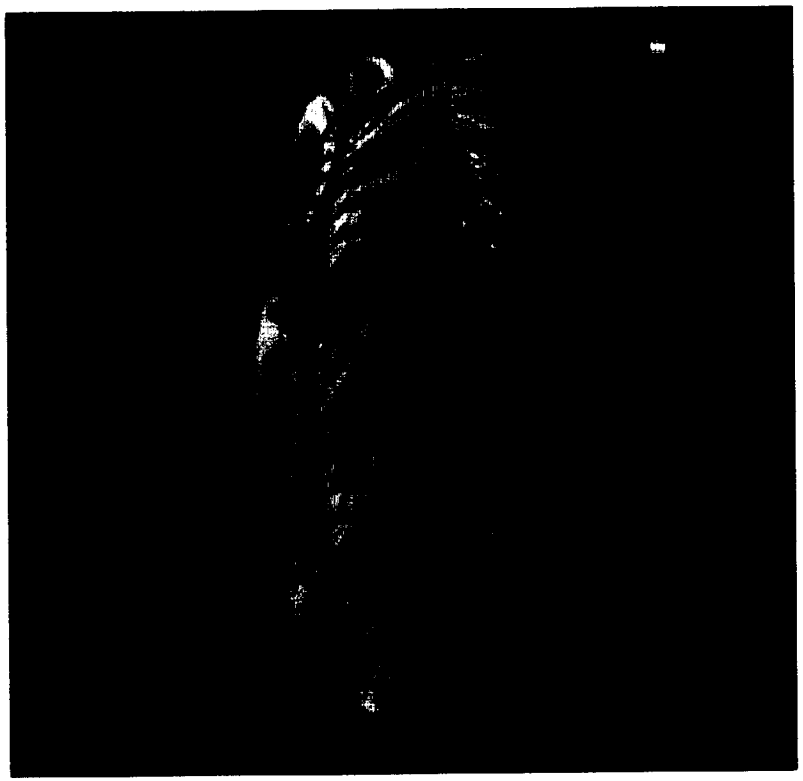
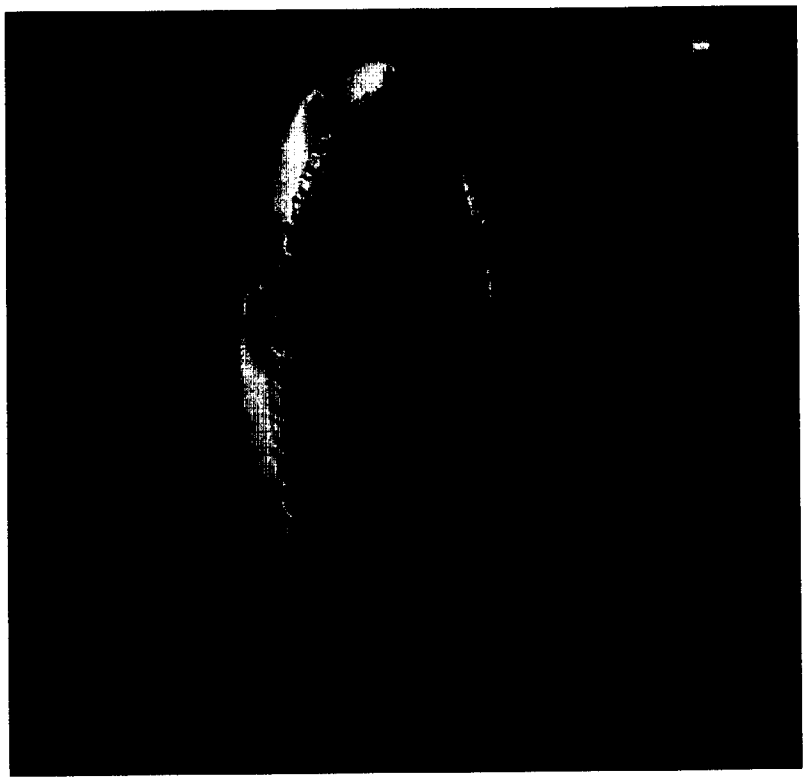
Comparison of Full and Partial Admission Flow Fields in the Simplex Turbine





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10 September 2001

Outline

- **Motivation**
- **Flow code description - CORSAIR**
  - Capabilities
  - Future directions
- **Results**
  - Full admission Simplex turbine
  - Partial admission Simplex turbine
- **Conclusions**

Motivation

- **Determine the effects of partial admission flow on:**
  - rotor performance as a function of circumferential location
  - unsteady rotor loading
- **Provide an efficient technique for determining turbine performance**

Flow Code Capabilities - I

- **CORSAIR**
  - Unsteady time-dependent equations of motion
  - Full Navier-Stokes, thin-layer Navier-Stokes or Euler
  - Variable fluid properties (Cp, gamma)
- **Third-order spatial discretization of inviscid fluxes**
  - Roe's scheme
- **Second-order spatial discretization of viscous fluxes**
  - Standard central differences
- **Second-order temporal accuracy**
- **Multi-block O-H grid topology**
  - O-grids around airfoils and in tip clearance regions
  - H-grids for remainder of flow field and nozzles
  - Well-suited for medium-to-fine grain parallel simulations

Flow Code Capabilities - II

- **Turbulence models**
  - Highly-modified Baldwin-Lomax model
- **Transition models**
  - Abu-Ghannam and Shaw (natural)
  - Mayle (natural)
  - Modified Roberts' correlation (bubble)
- **Boundary conditions**
  - Steady and unsteady inlet and exit
  - Specified wall temperature or heat flux
  - Film cooling/mass injection
  - Actuator disk
  - Component linking
- **Grid Motion**
  - Arbitrary translation/rotation
  - Blade vibration

Flow Code Capabilities - III

- **MPI and OpenMP used for parallel simulations**
  - decomposition by blade row
  - decomposition by blade passage
  - decomposition by O- and H-grids
  - decomposition by component
  - user specified decomposition
- **Graphical User Interface**
  - Grid generation
  - Flow solver
  - Error checking
  - Design page
  - User's manual/help facility
  - Post-processing
- **Miscellaneous capabilities**
  - Conjugate heat transfer capability
  - Provides unsteady pressure file for stress analysis
  - Provide Fourier decomposition of unsteady pressures
  - Will run on any Unix, Linux or Windows NT platform

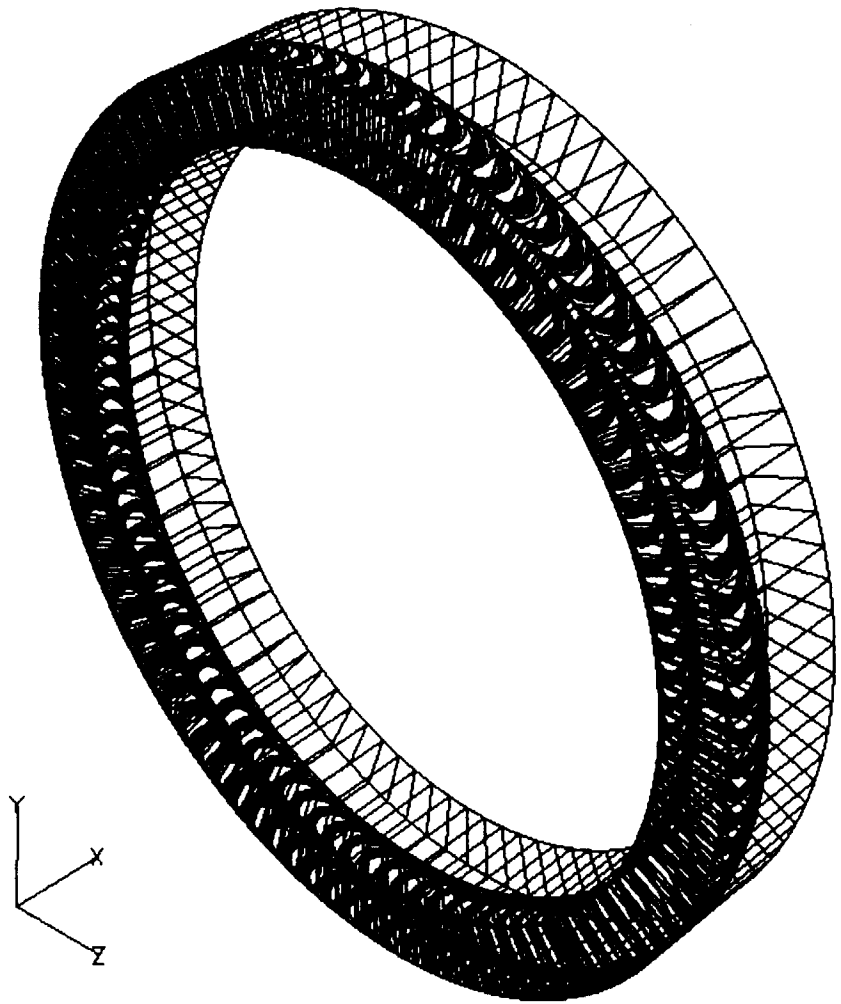
CORSAIR Future Directions

- **Modifying code for pump geometries**
  - incorporating incompressible flow physics
- **Incorporate two-phase flow modeling**
- **Incorporate cavitation modeling**

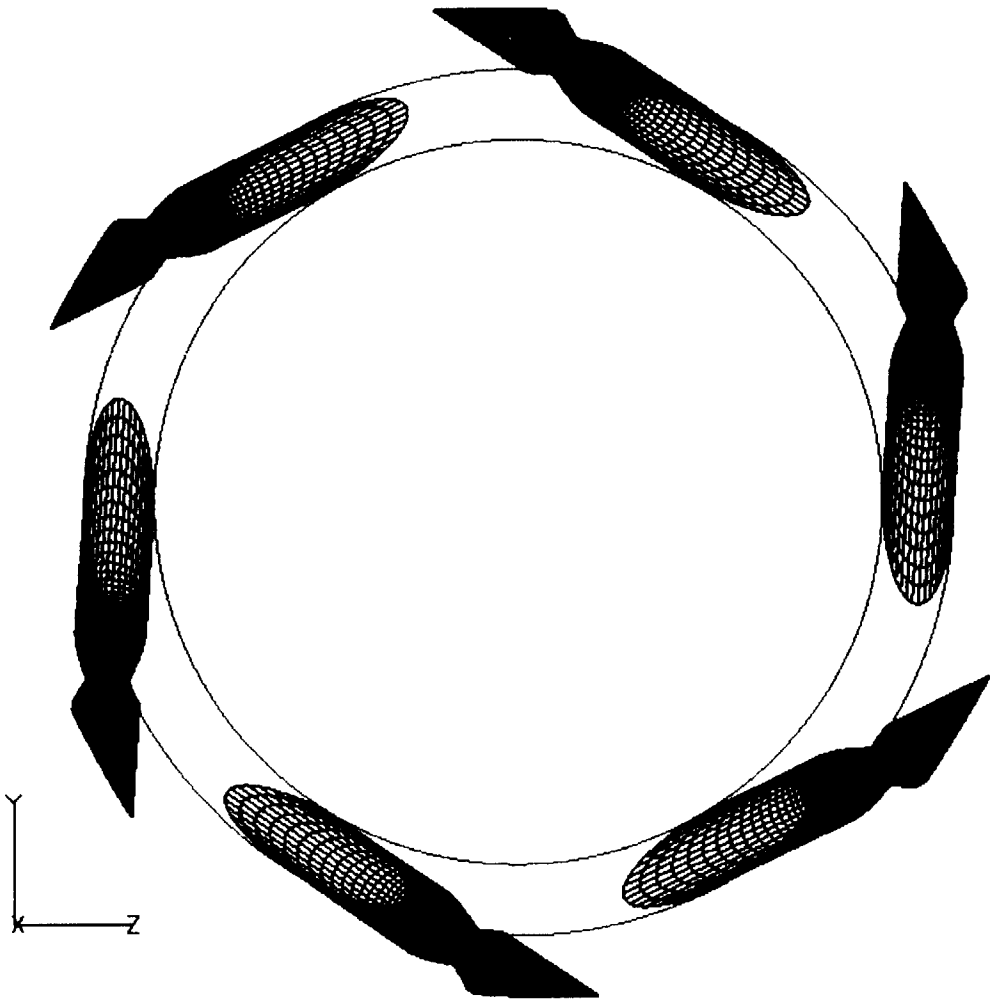
Simplex Turbine Simulations

- **Objective - determine the effects of partial admission on the rotor unsteady load and performance as a function of circumferential location**
- **Full-Admission simulation (FA)**
  - 1 nozzle and 8 rotors modeled
  - 750,000 grid points
  - 8 full cycles (one complete rotor revolution) completed
- **Partial-Admission simulation (PA)**
  - 6 nozzles and 95 rotors modeled
  - 7 million grid points
  - 0.95 revolutions completed
  - PA-IN - in region of nozzle flow
  - PA-OUT - outside the region of nozzle flow

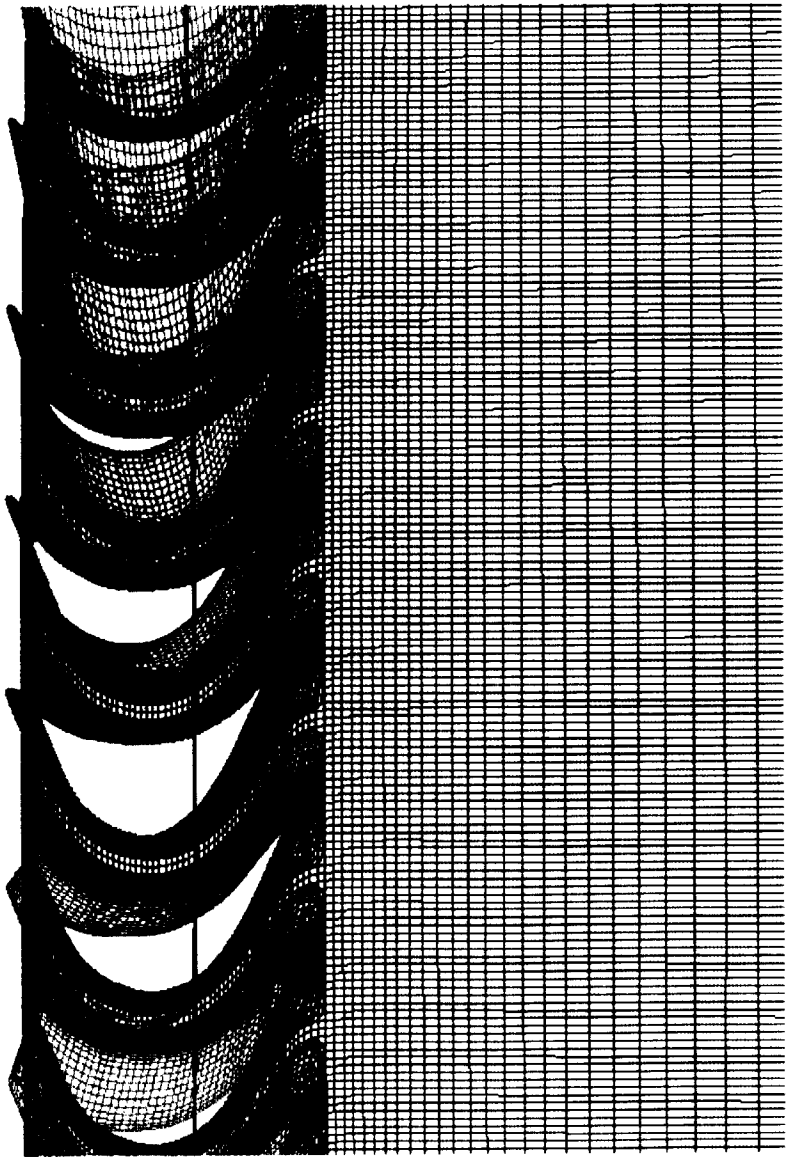
Simplex Turbine Rotors



Simplex Turbine Nozzles

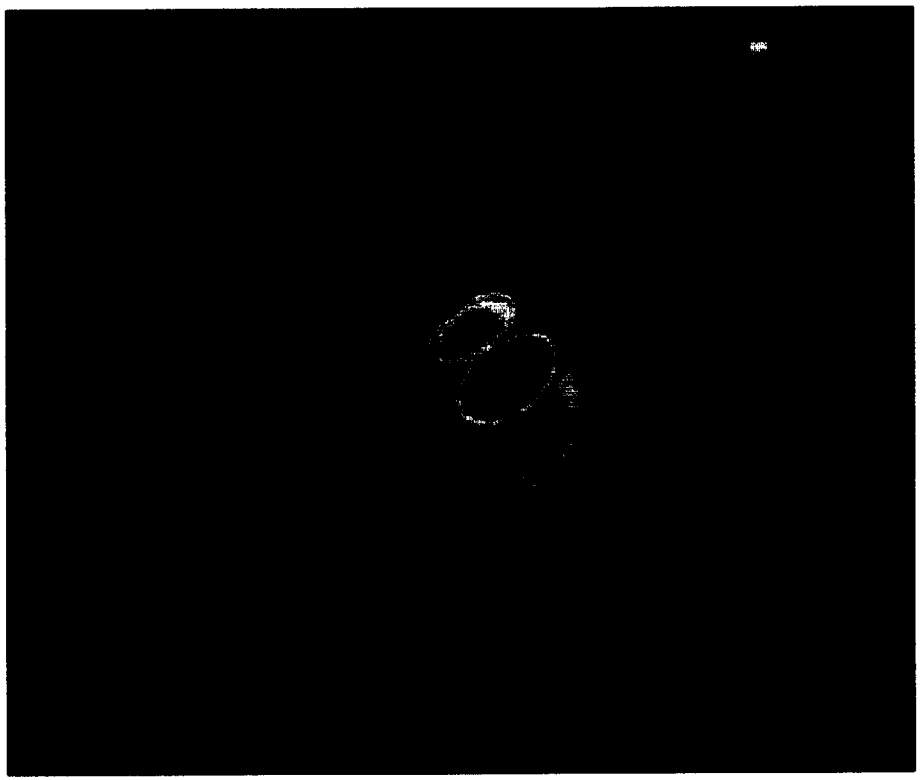


Computational Grids - Rotor

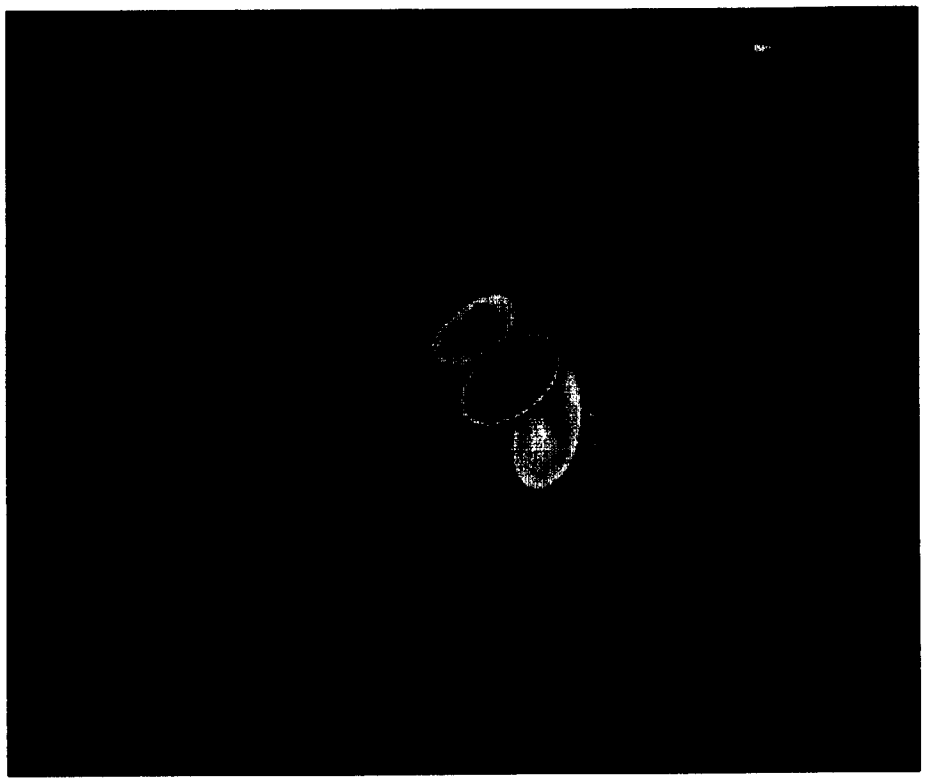


Nozzle/Rotor Interface - Mach Number (PA)

Instantaneous Mach Number - Nozzle

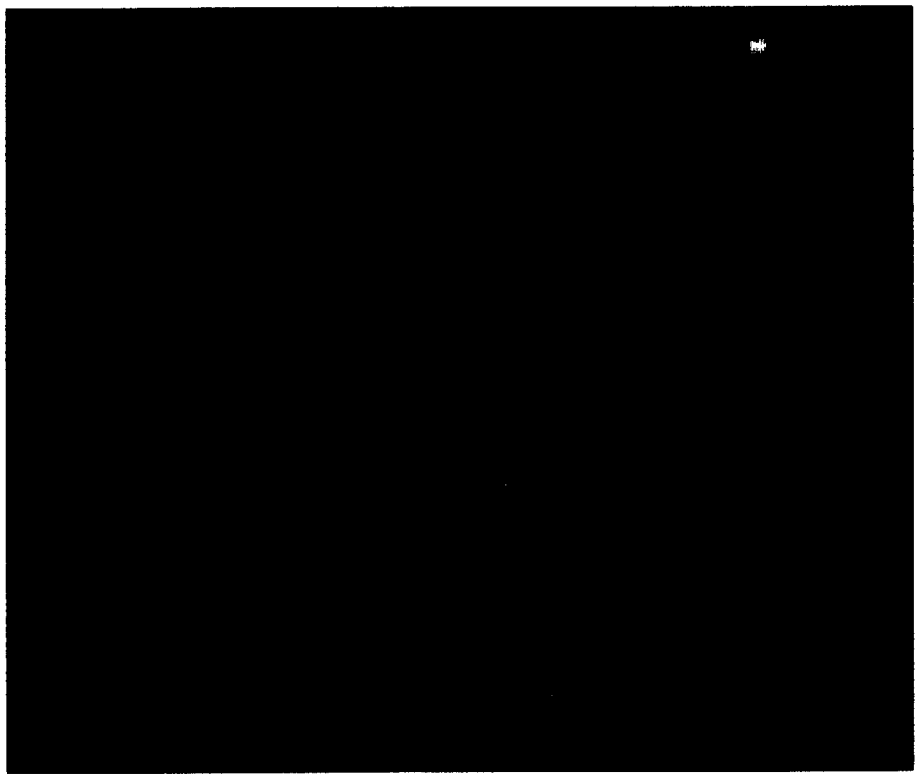


FULL ADMISSION



PARTIAL ADMISSION

Instantaneous Mach Number - Nozzle



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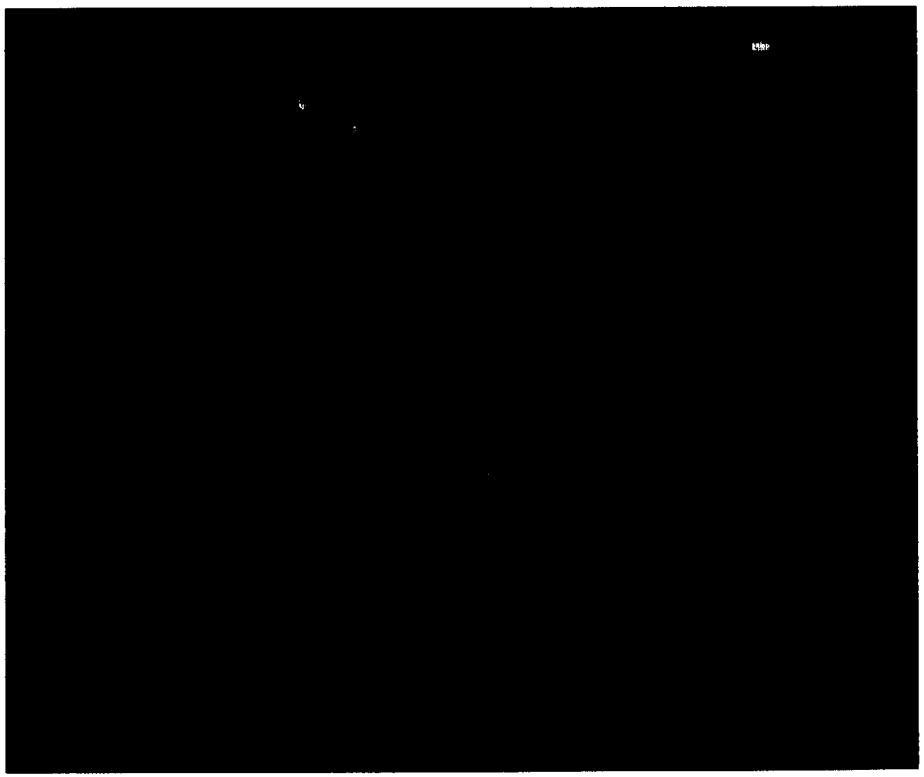

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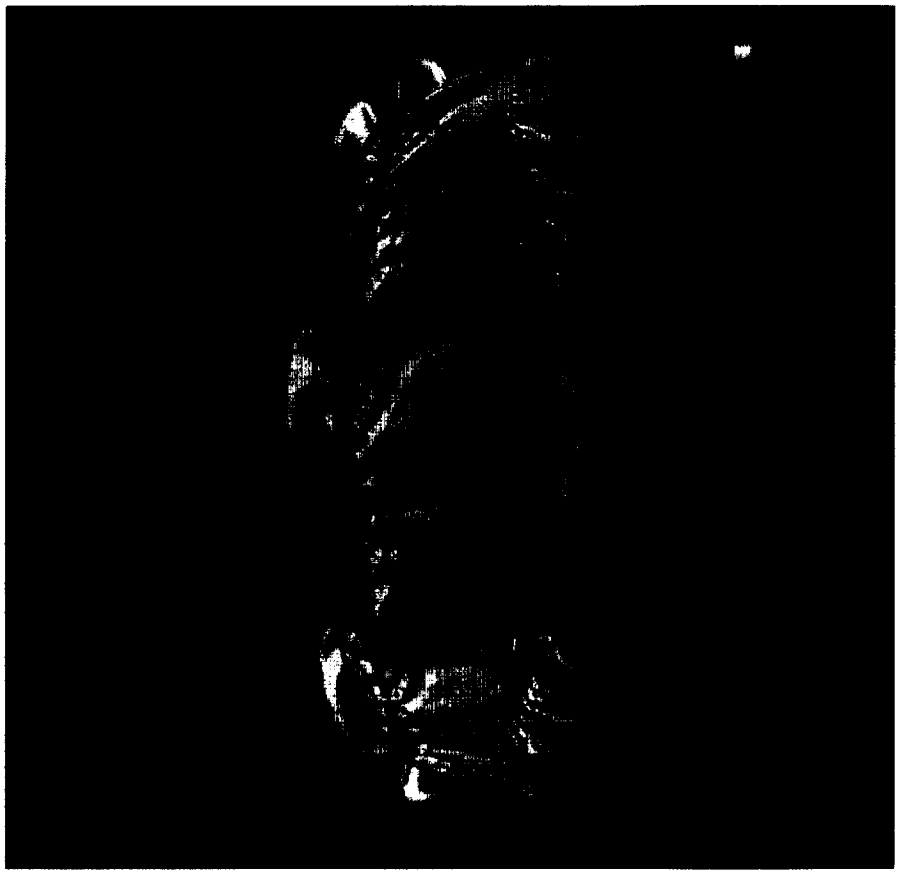
Instantaneous Mach Number



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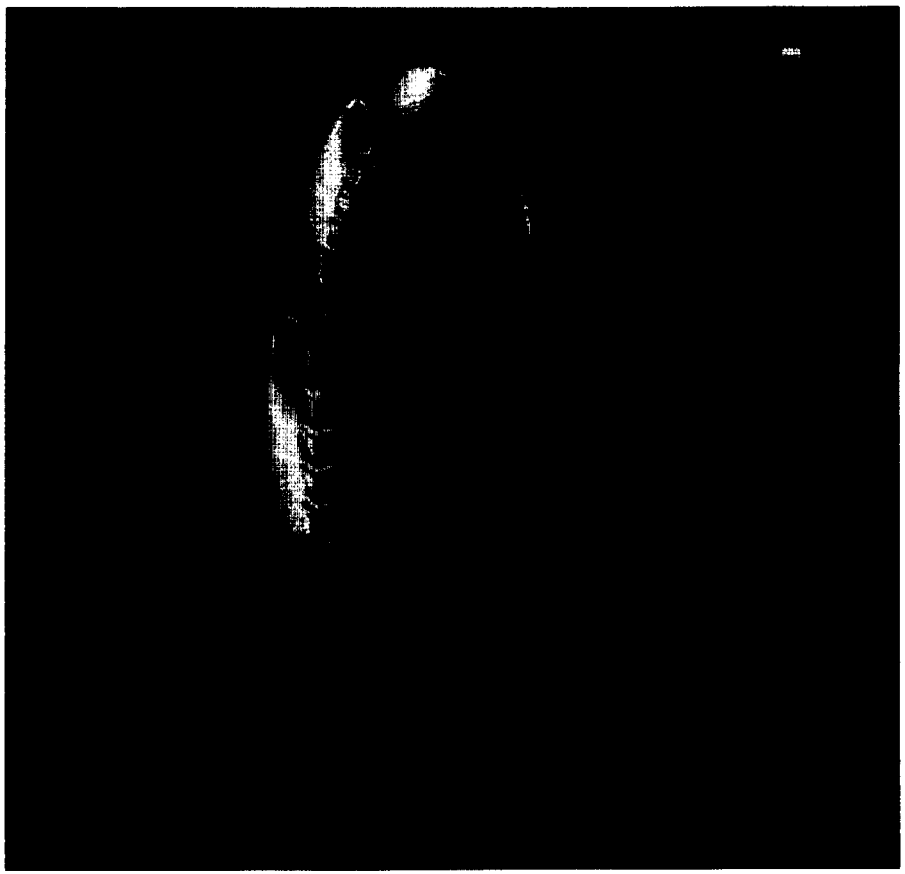
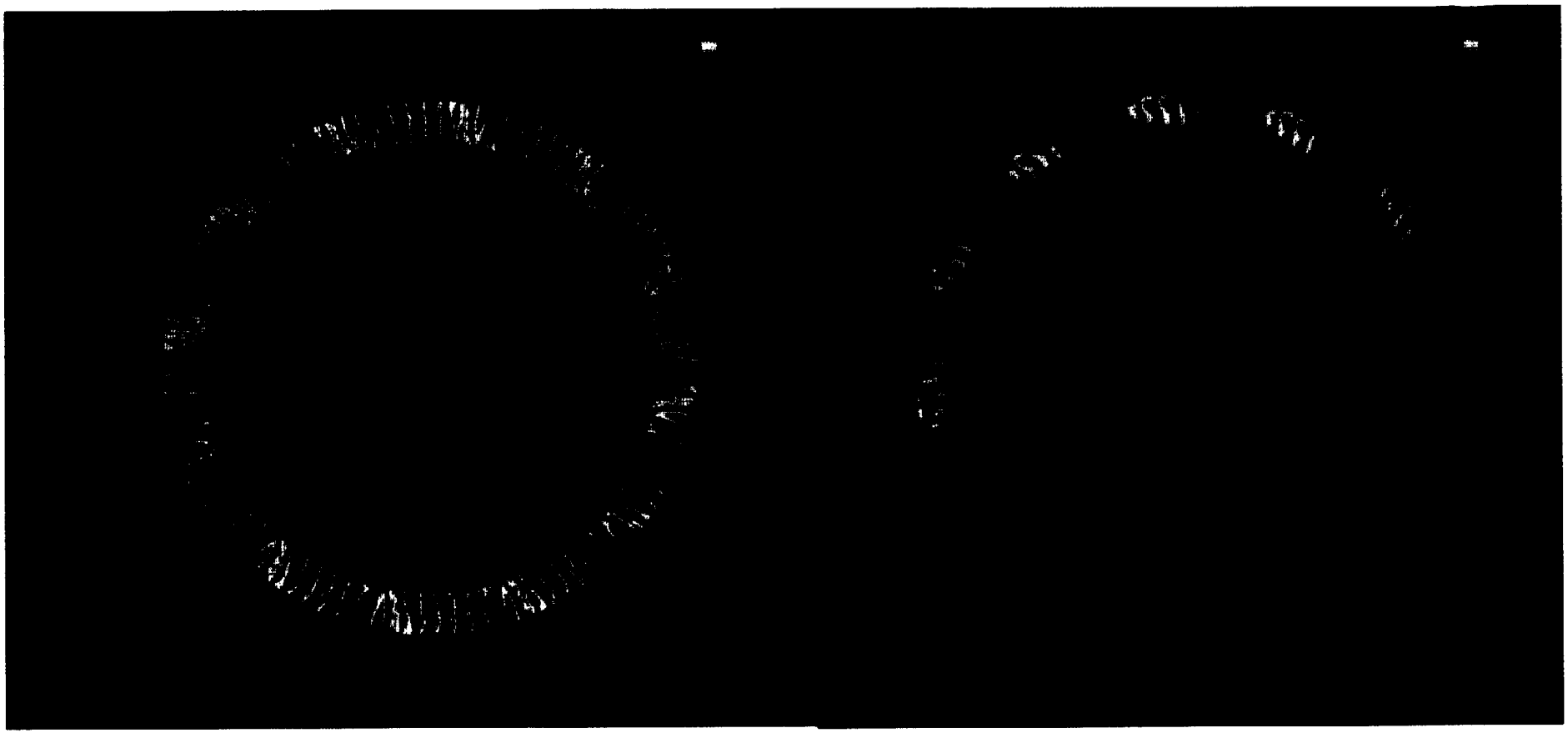


PARTIAL ADMISSION

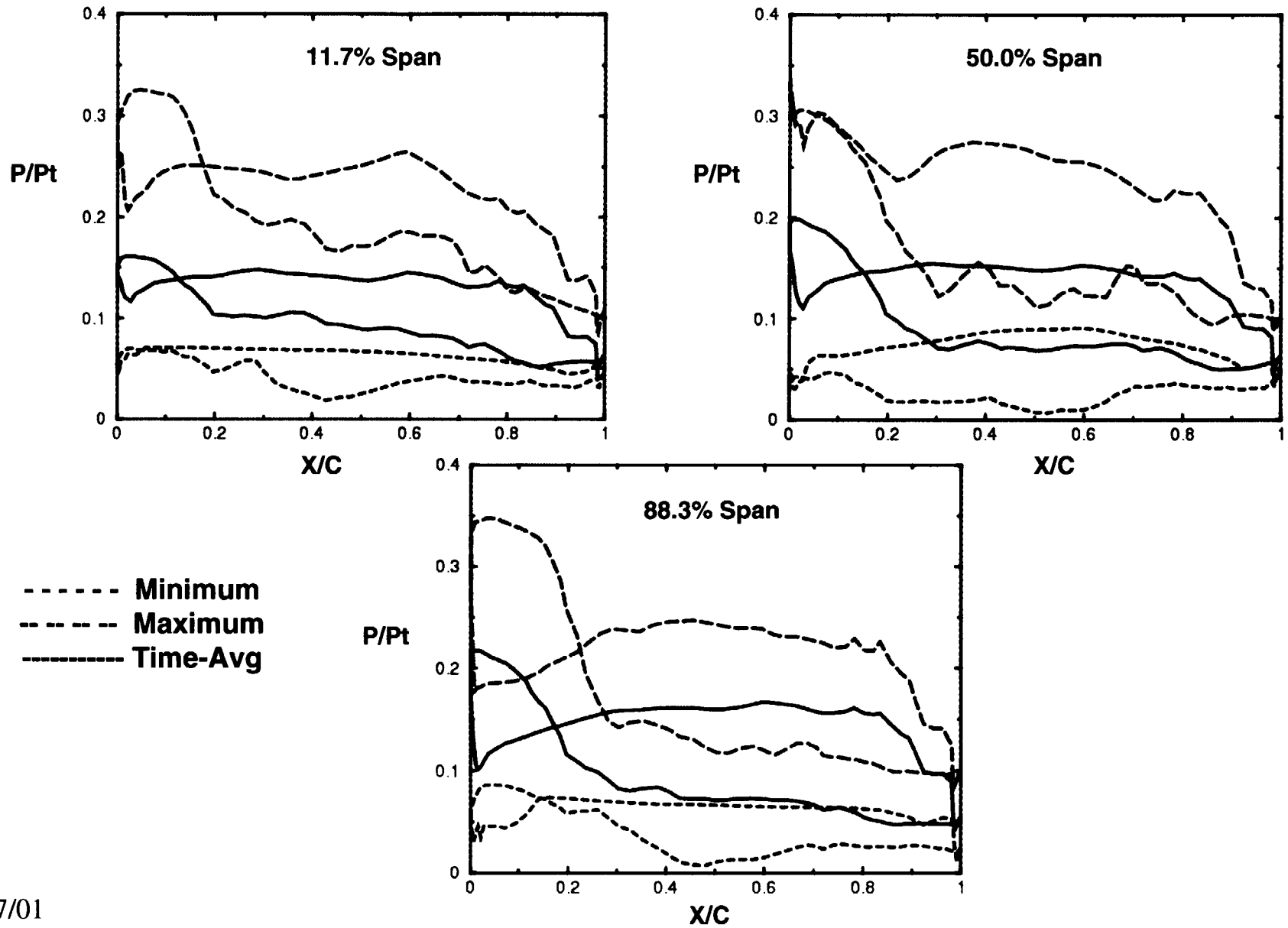
Instantaneous Mach Number - Rotor Exit



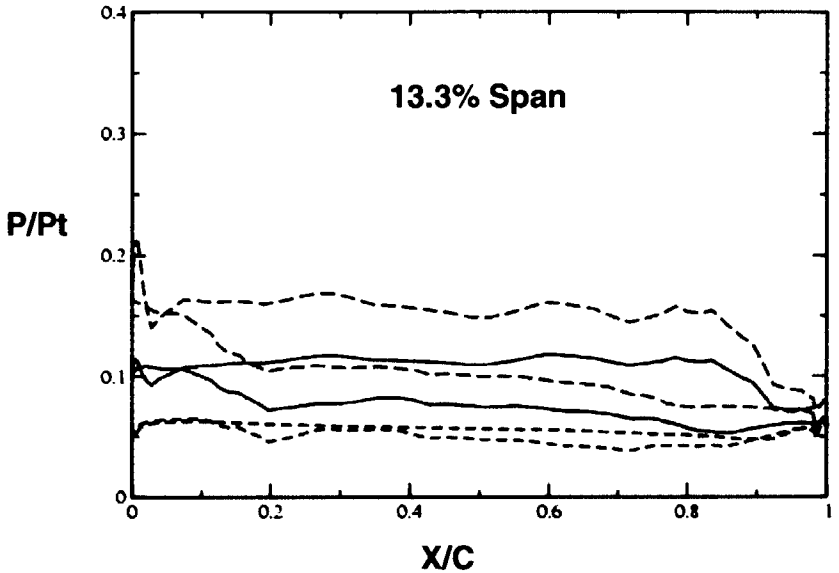
FULL ADMISSION

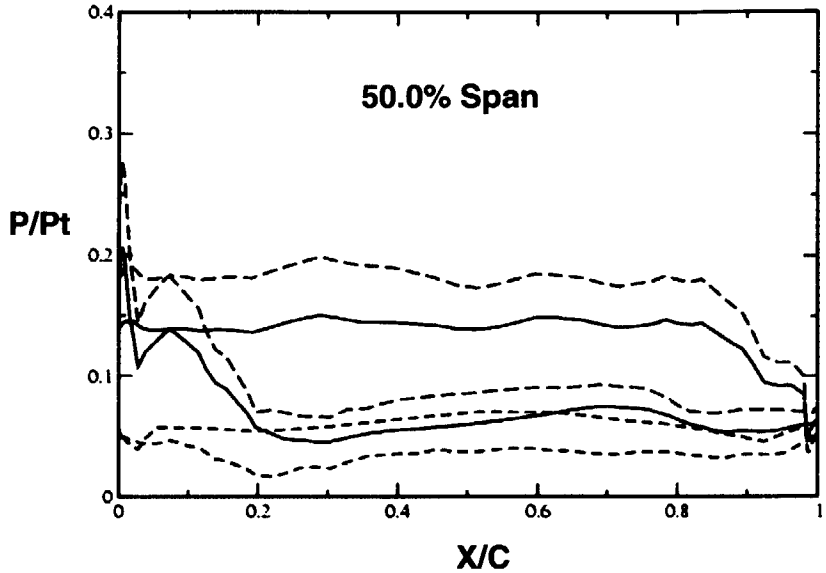
PARTIAL ADMISSION

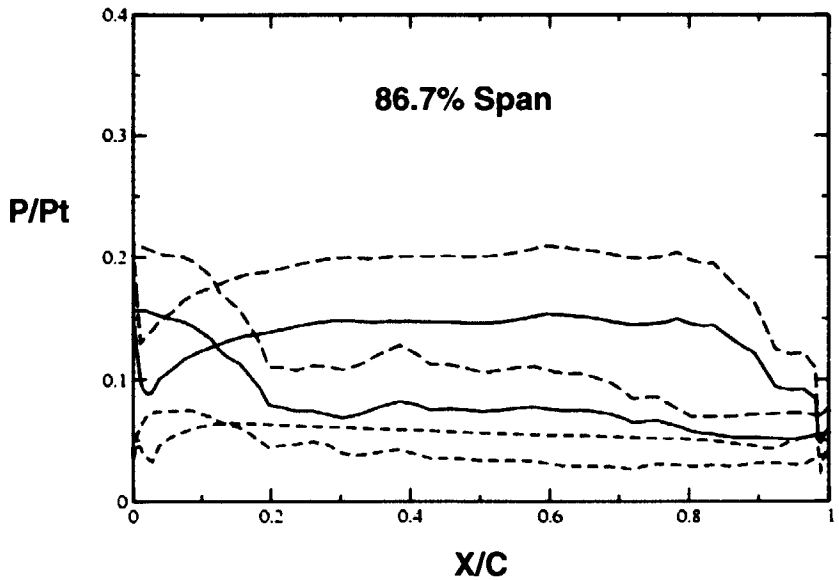
Unsteady Rotor Pressure Envelopes (FA)



Unsteady Rotor Pressure Envelopes (PA-IN)

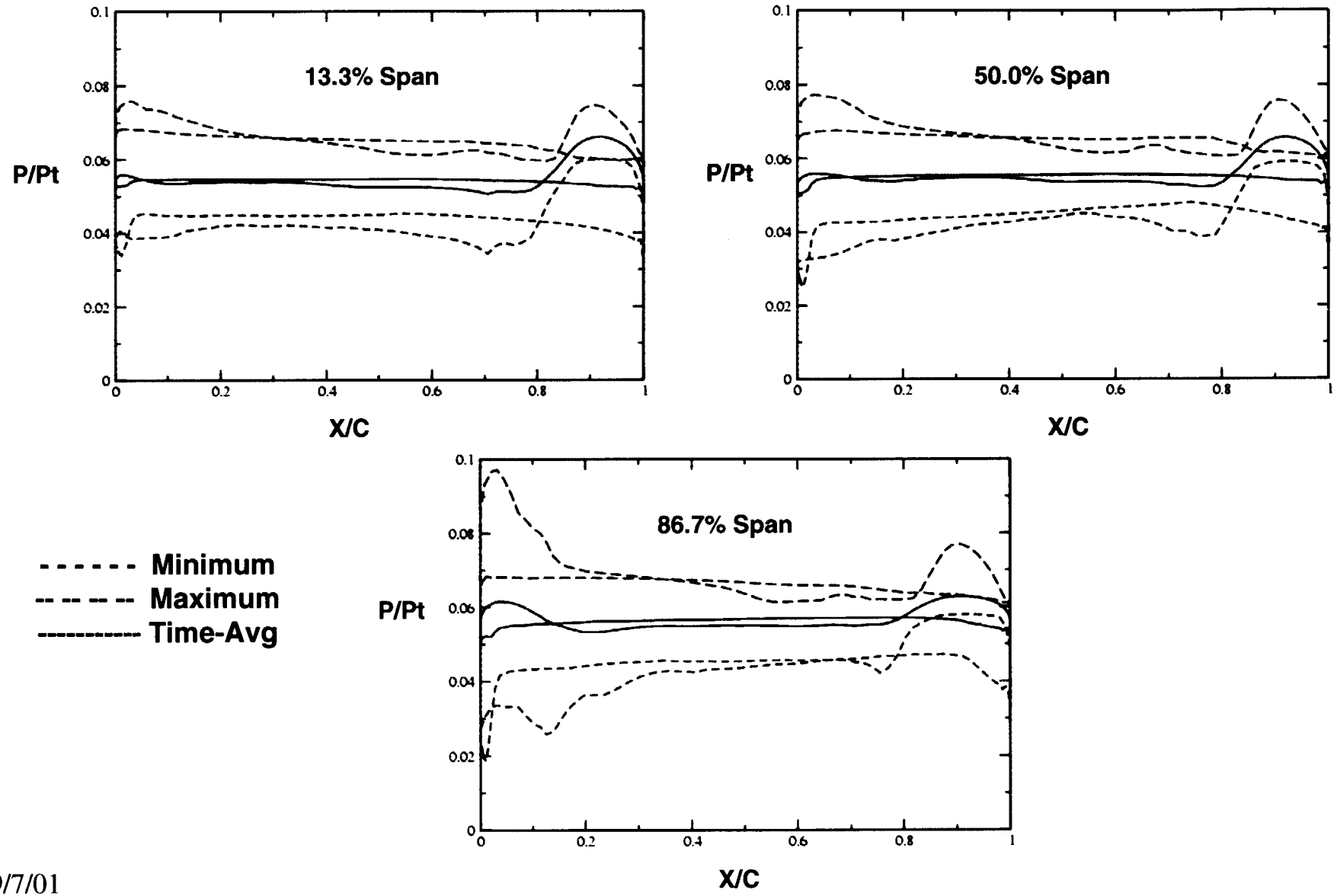




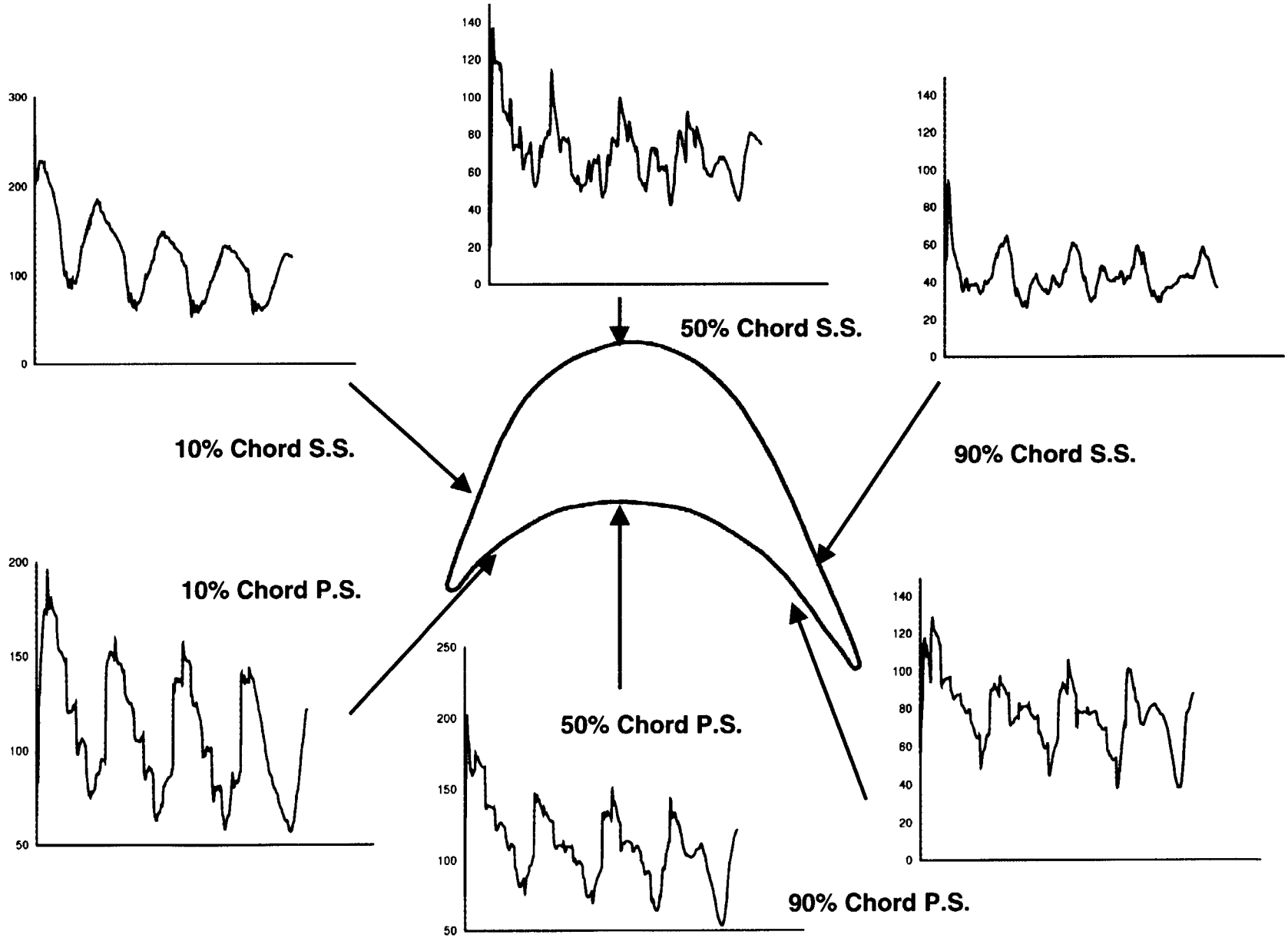


- - - - - - Minimum
-- -- -- -- Maximum
---------- Time-Avg

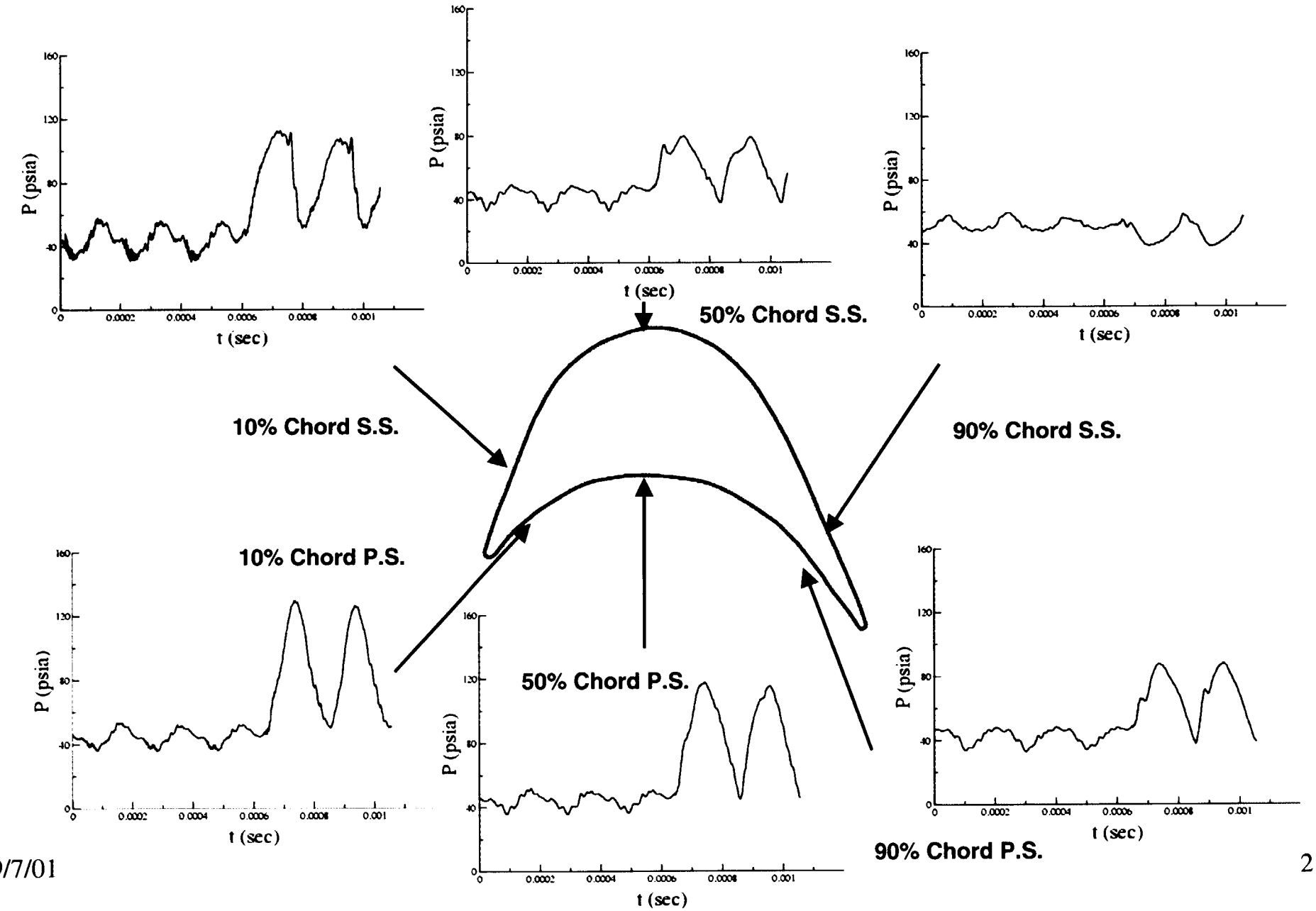
Unsteady Rotor Pressure Envelopes (PA-OUT)



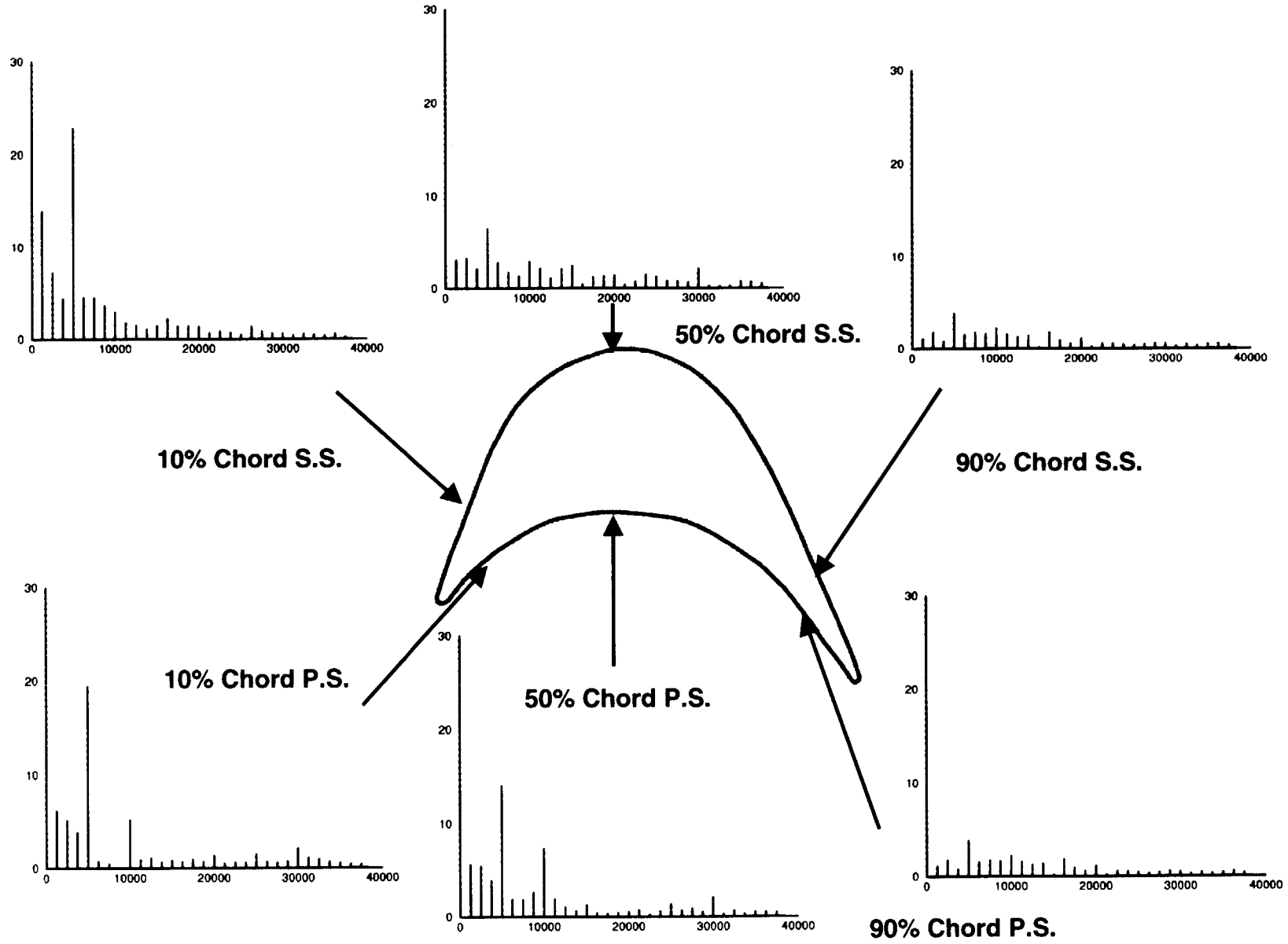
Unsteady Pressure - 11.7% Span (FA)



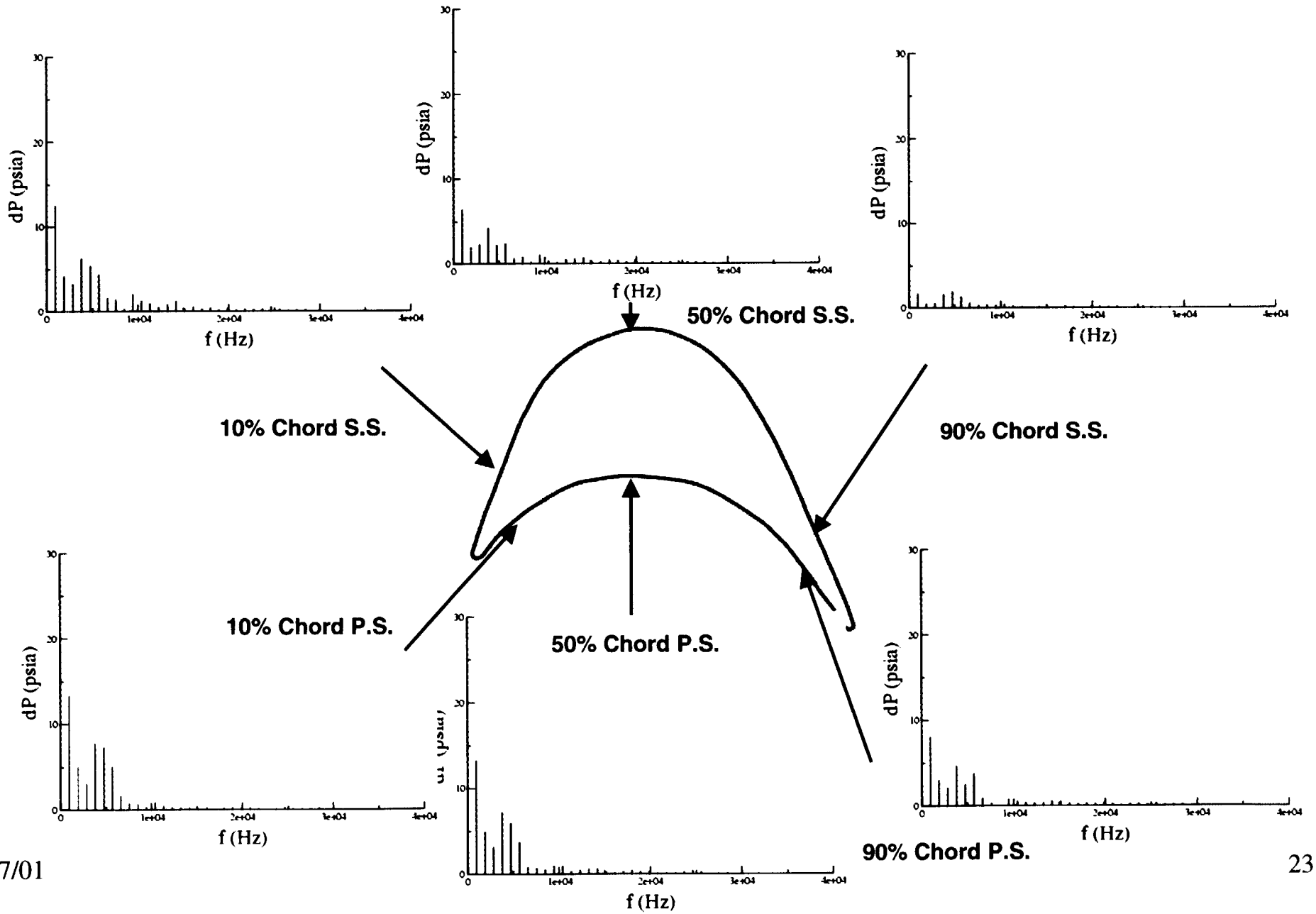
Unsteady Pressure - 13.3% Span (PA)



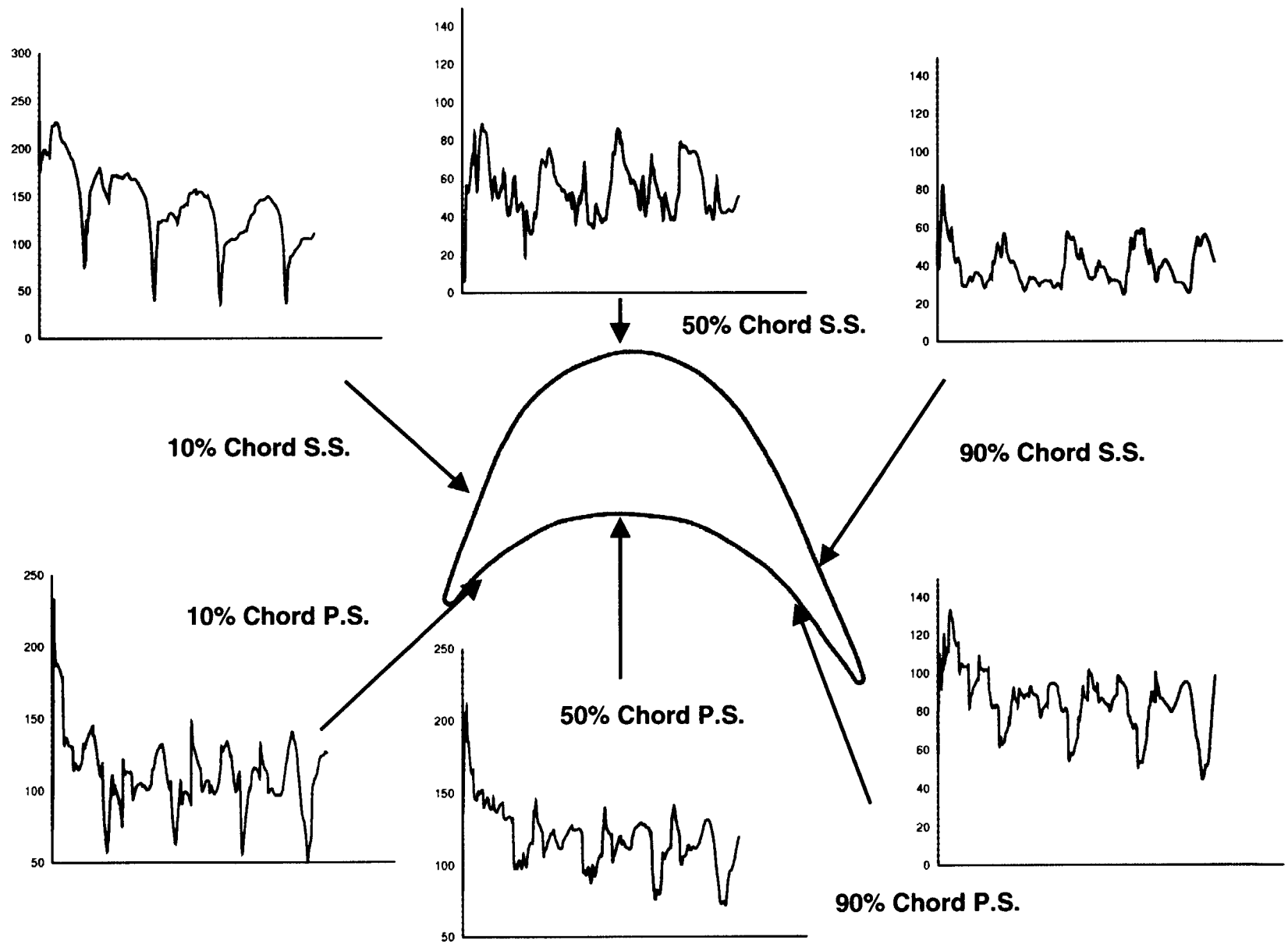
Unsteady Decomposition - 11.7% Span (FA)



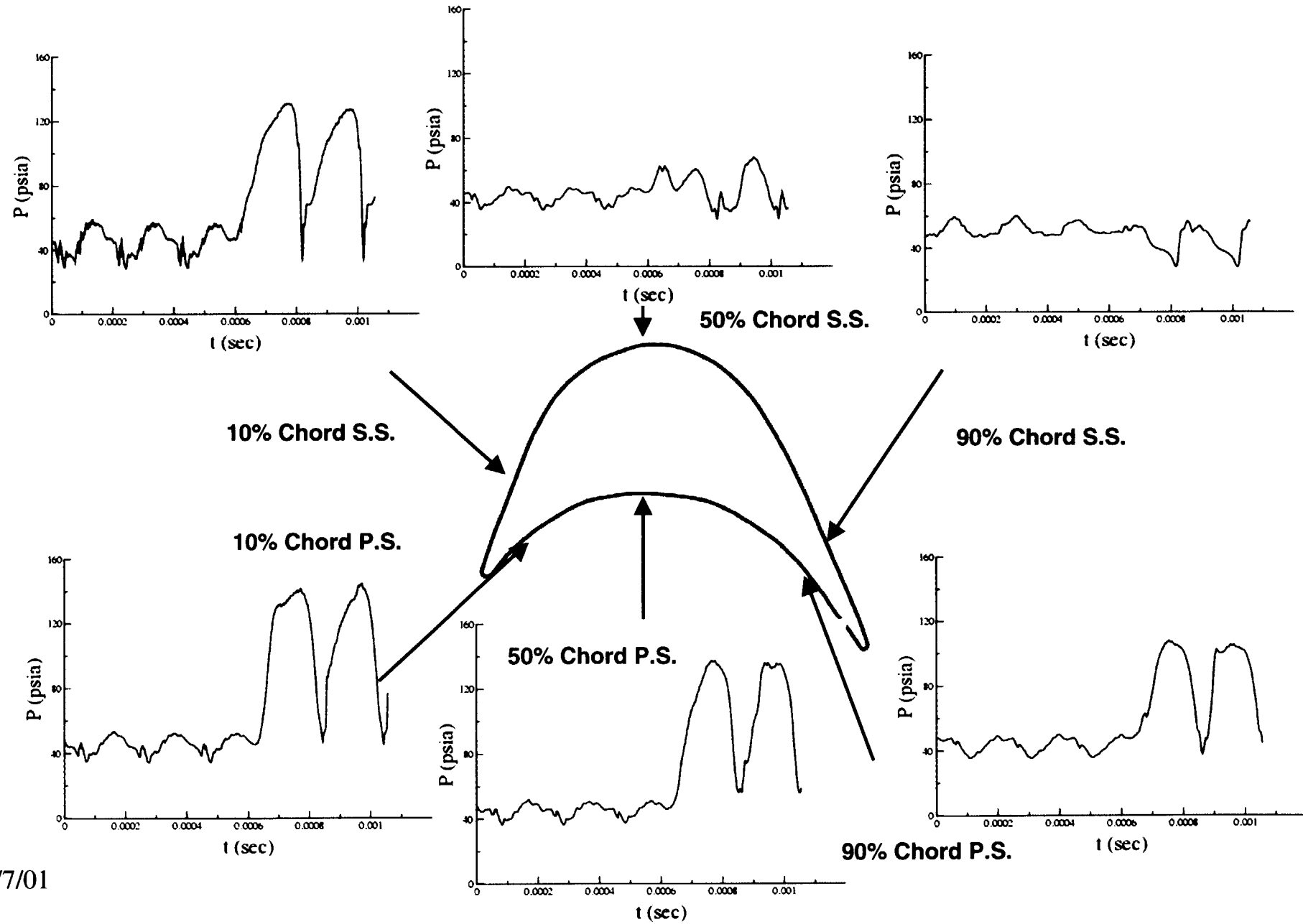
Unsteady Decomposition - 13.3% Span (PA)



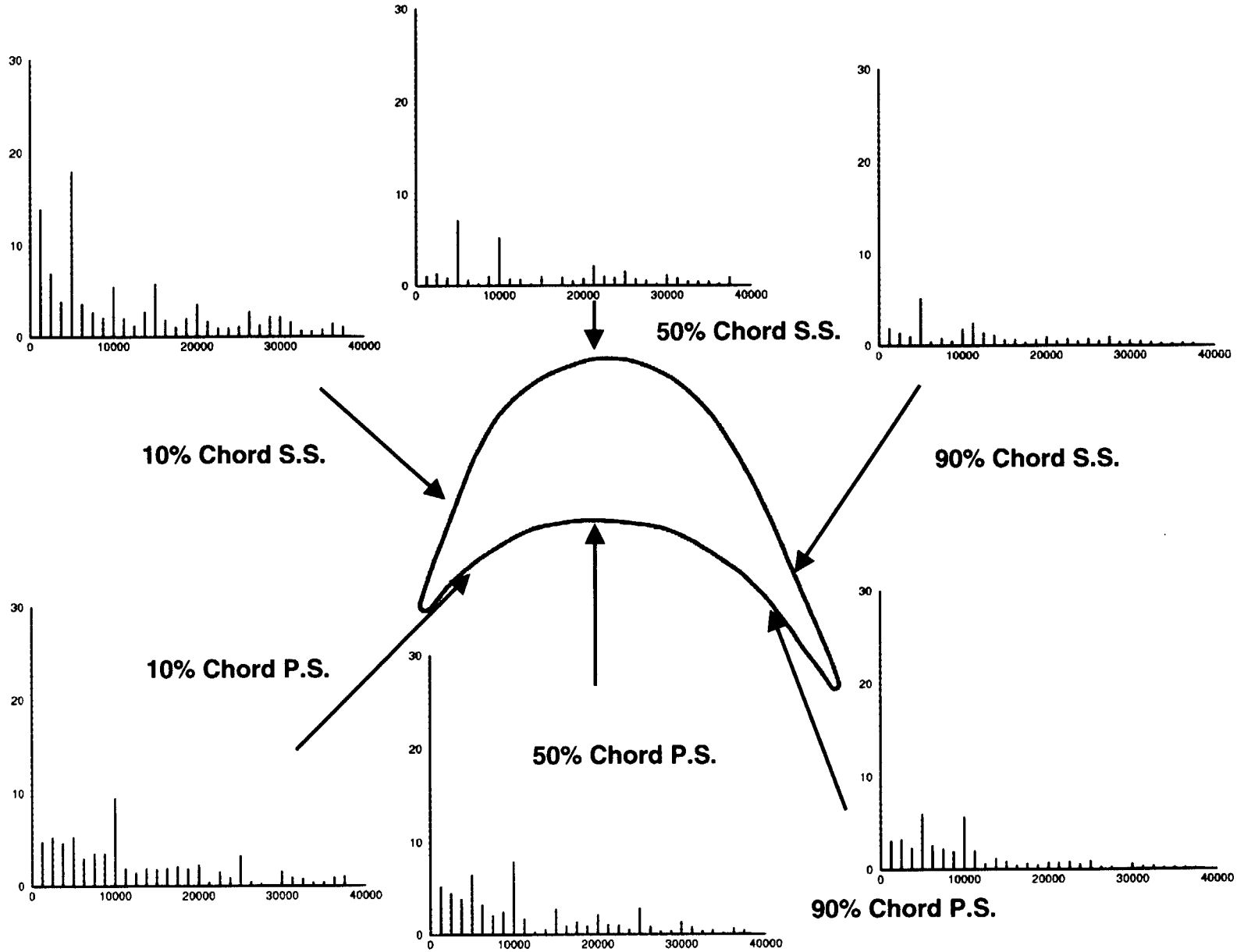
Unsteady Pressure - 50.0% Span (FA)



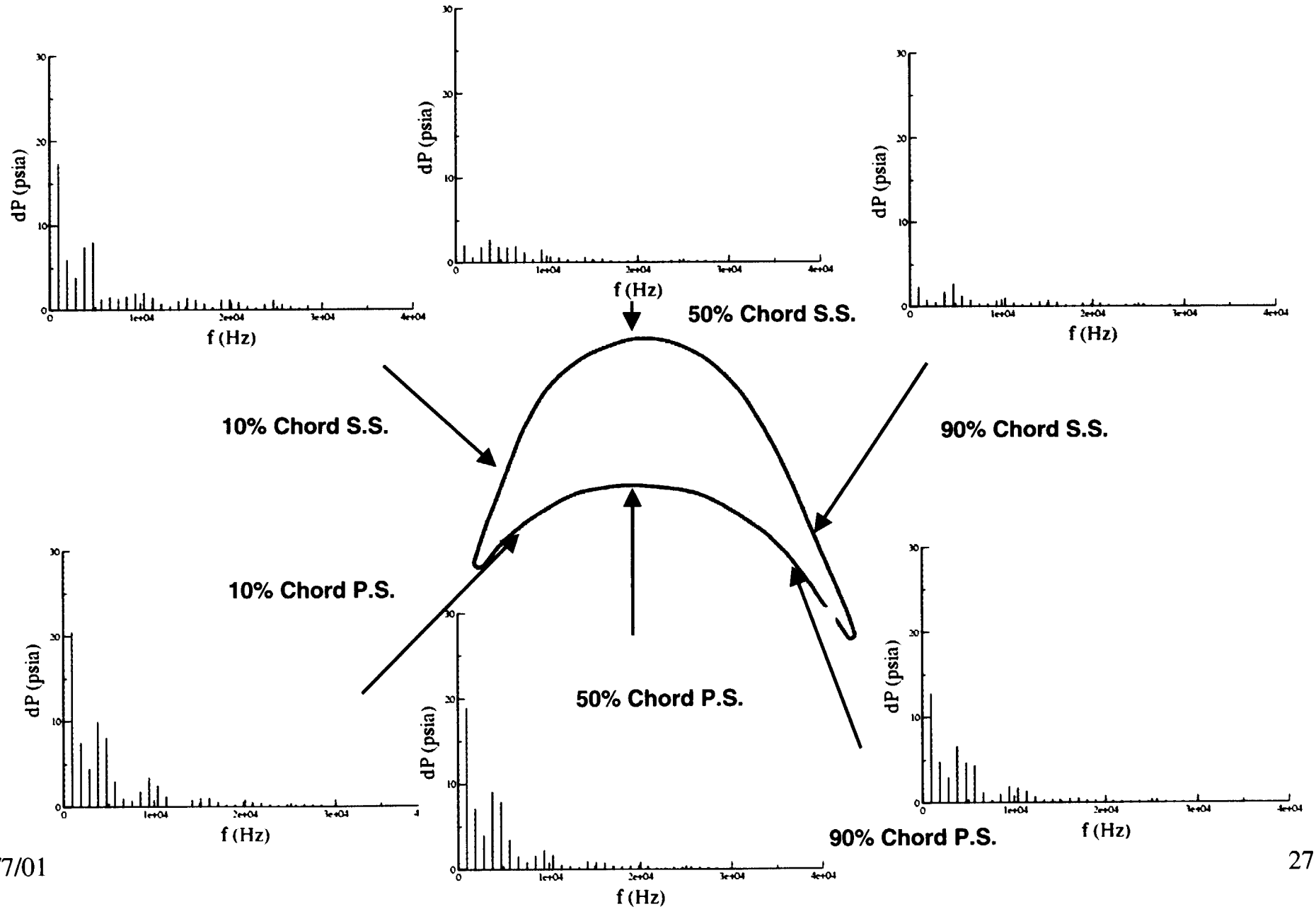
Unsteady Pressure - 50.0% Span (PA)



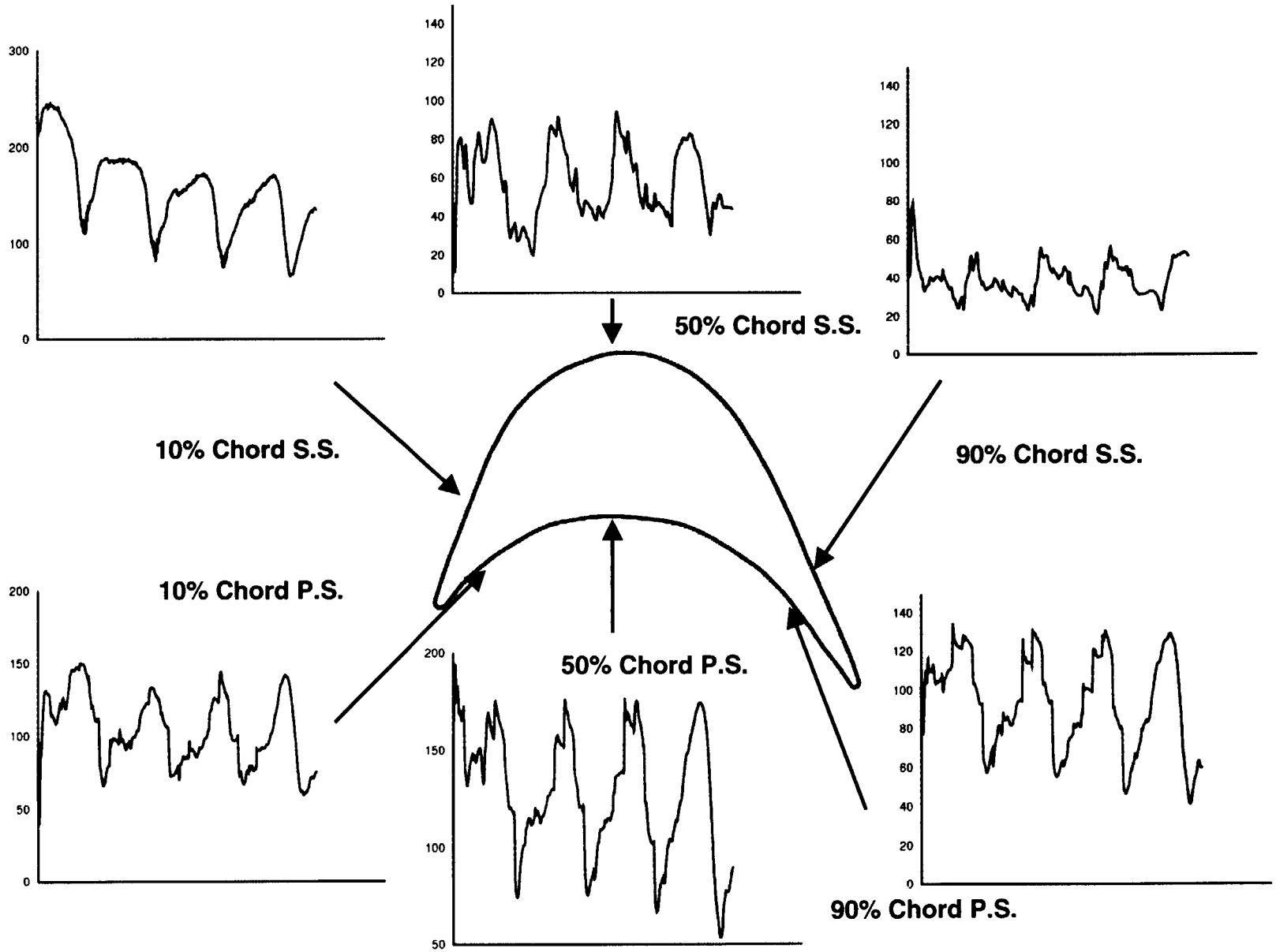
Pressure Decomposition - 50.0% Span (FA)



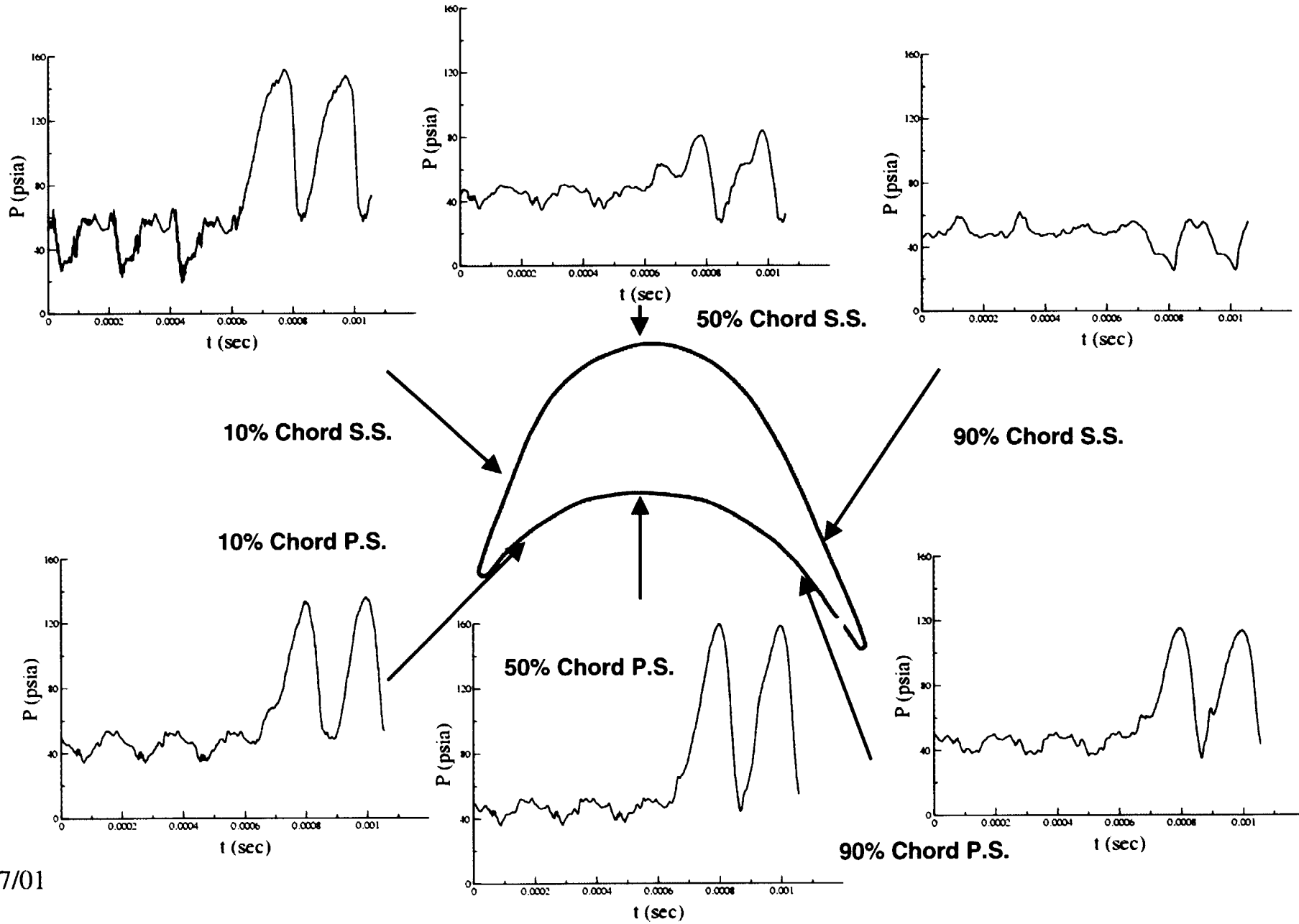
Pressure Decomposition - 50.0% Span (PA)



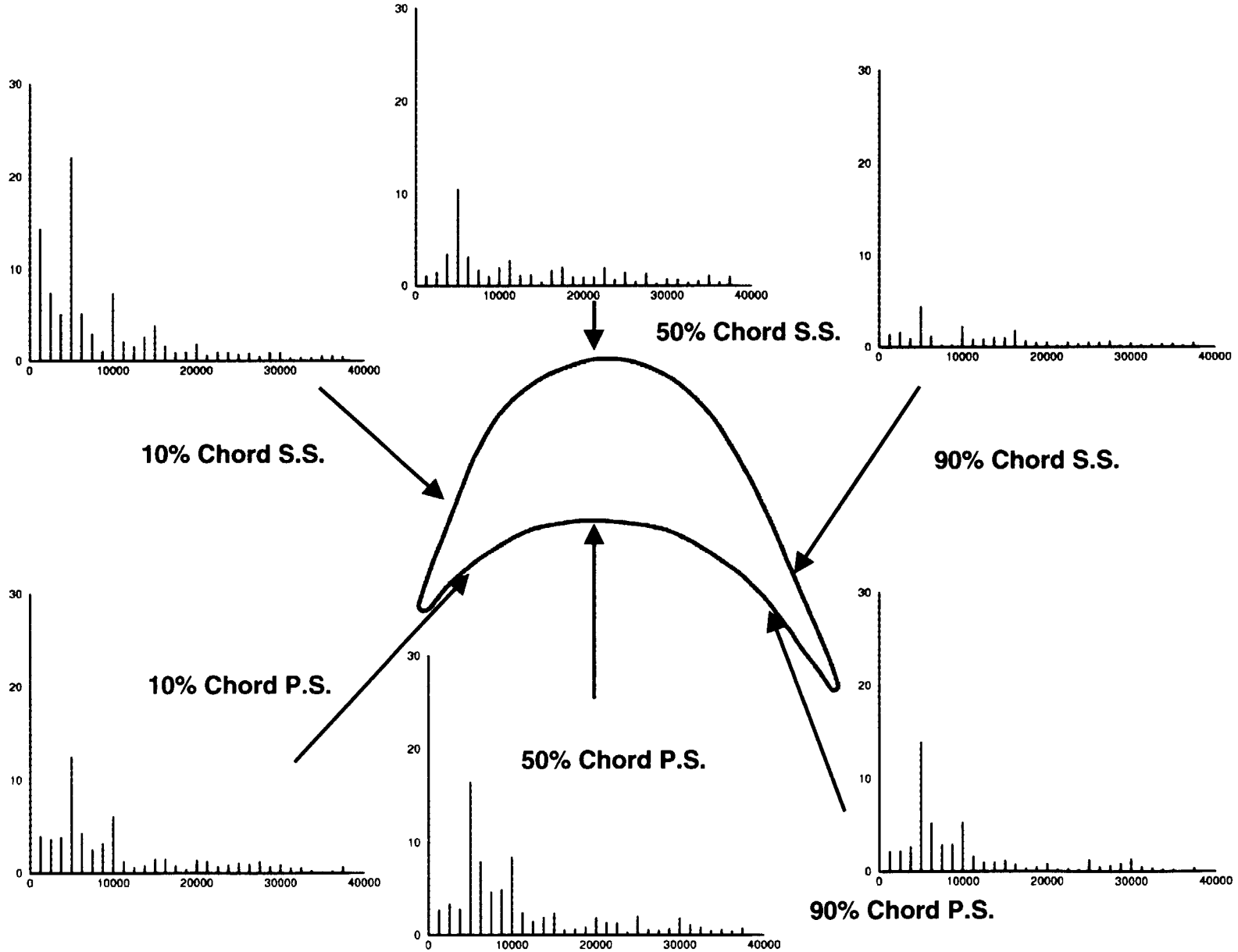
Unsteady Pressure - 88.3% Span (FA)



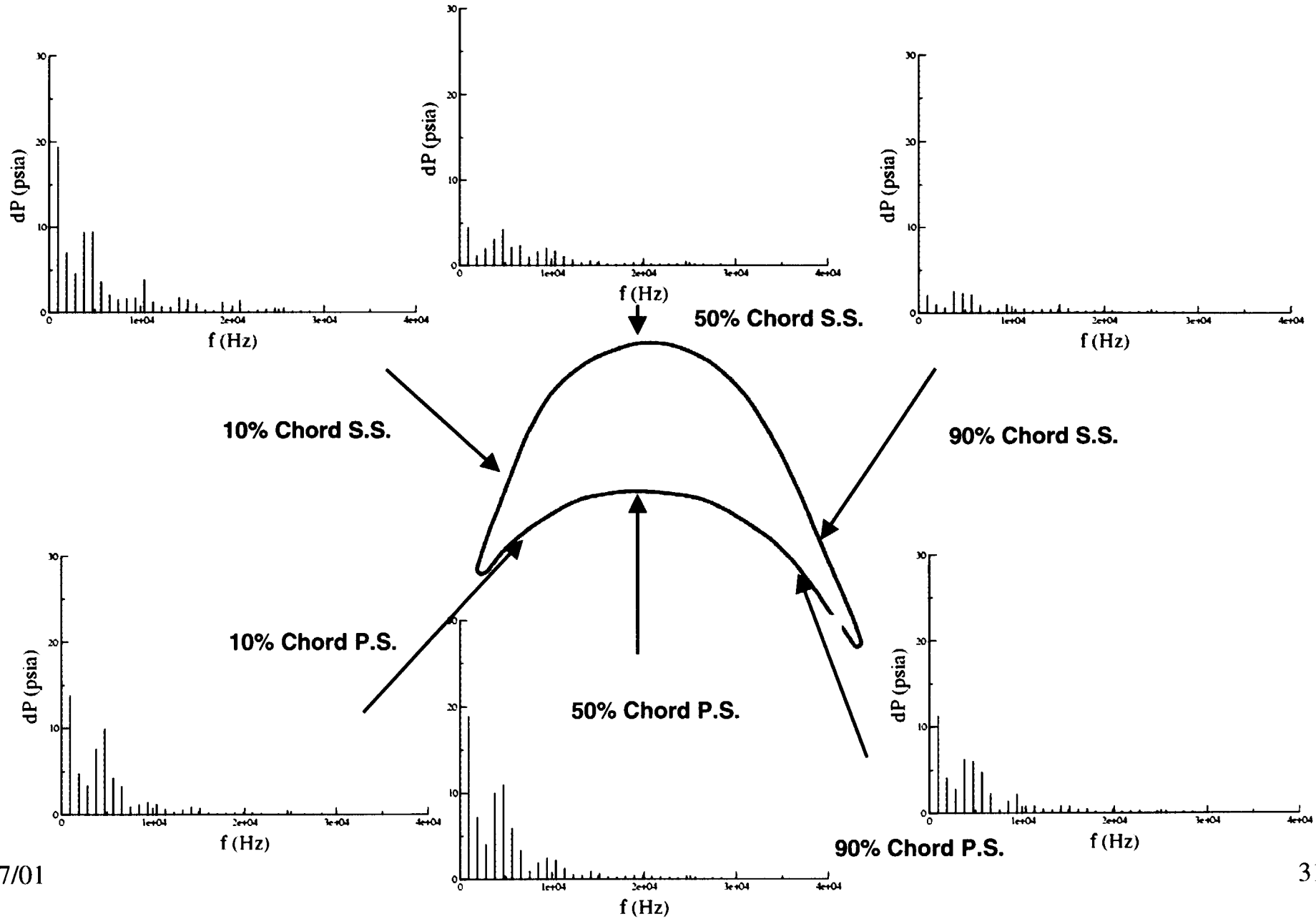
Unsteady Pressure - 86.7% Span (PA)



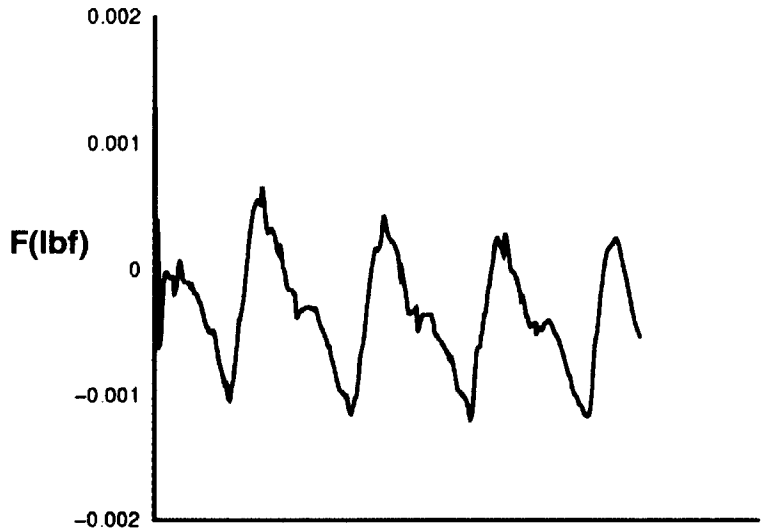
Pressure Decomposition - 88.3% Span (FA)



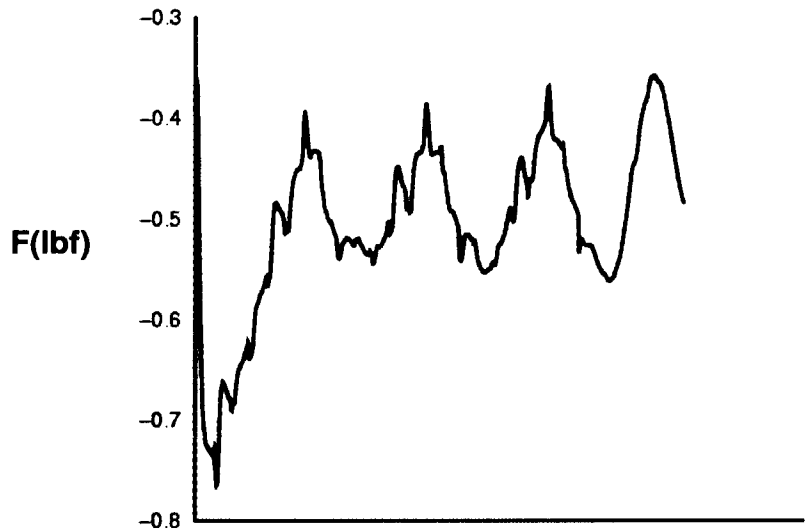
Pressure Decomposition - 86.7% Span (PA)



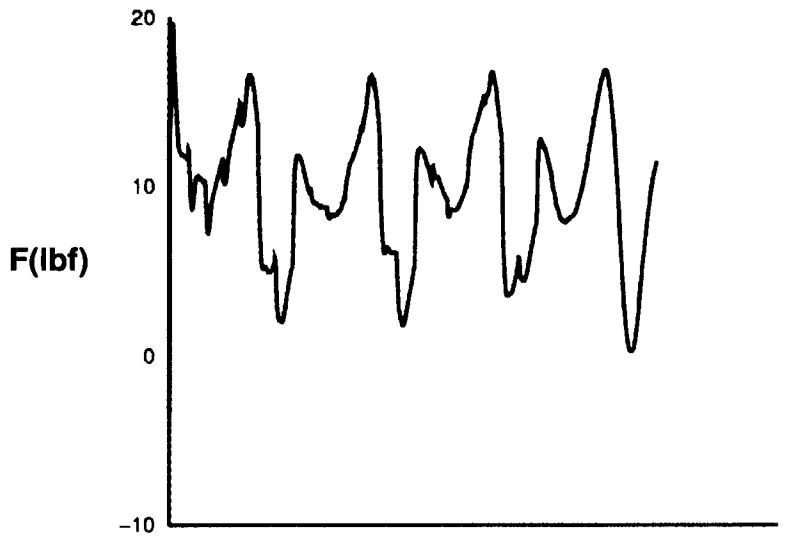
Unsteady Integrated Forces (FA)



Axial Force

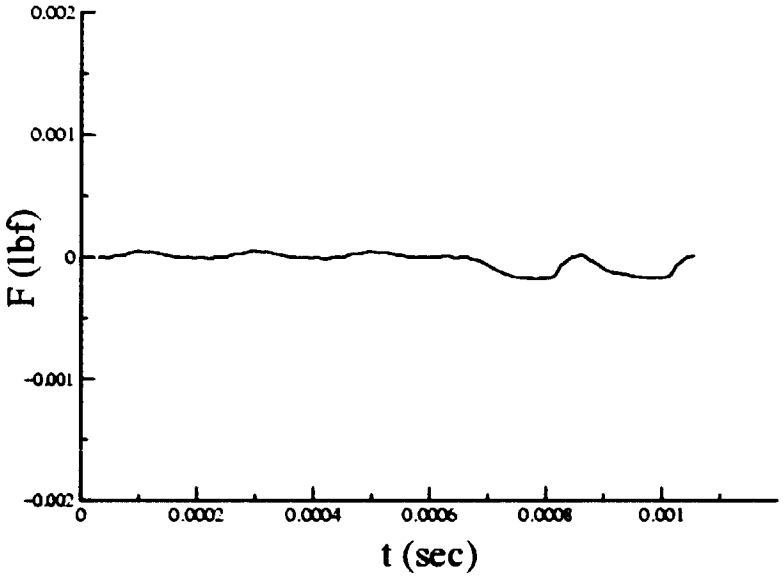


Radial Force

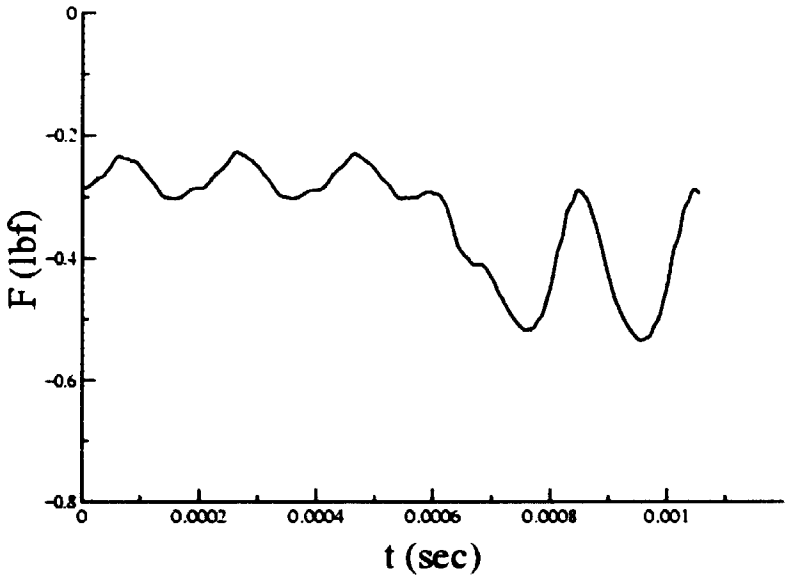


Tangential Force

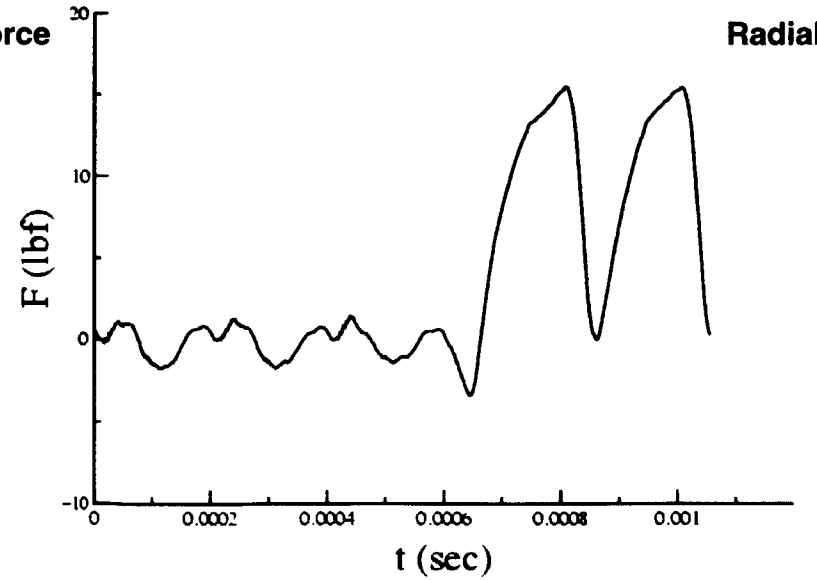
Unsteady Integrated Forces (PA)



Axial Force



Radial Force



Tangential Force

Conclusions

- **Full admission simulation performed for the Simplex turbine**
  - models one nozzle and 12 rotors
  - Mach number of flow exiting nozzle low
  - Mach number at rotor exit too high
  - unsteadiness predominantly a nozzle-passing and twice nozzle-passing frequency
- **Partial admission simulation underway for Simplex turbine**
  - models all nozzles and rotors
  - design Mach number obtained at nozzle exit
  - design Mach number obtained at rotor exit
  - unsteadiness at nozzle passing and lower frequenciers